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EVALUATION OF LOW COST ALUMINUM ALLOY GRANULES FOR USE IN ALUMINIZED EXPLOSIVES

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EVALUATION OF LOW COST ALUMINUM ALLOY GRANULES FOR USE IN ALUMINIZED EXPLOSIVES

by

Winona C. Hogge

NWSY TR 69-2

8 August 1969

Explosives, Physics and Chemistry Division
Explosives Engineering and Research Department

NAVAL WEAPONS STATION
Yorktown, Virginia 23491

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ABSTRACT: This report covers the evaluation of low cost aluminum alloy granules for use in aluminized explosives, i.e. Tritonal, DESTEX and H-6. The alloy was evaluated with respect to its effects on batching characteristics, composition uniformity, thermal stability and impact sensitivity of the explosive systems. A comparison was made of the alloy and currently used atomized aluminum with respect to particle size and chemical composition.

Submitted by

E. R. Cousins, Head
Explosives, Physics and Chemistry Division

NWSY TR 69-2 8 August 1969

EVALUATION OF LOW COST ALUMINUM ALLOY GRANULES FOR USE IN ALUMINIZED EXPLOSIVES

The evaluation herein described was carried out under ORDTASK No. ORD 332-002/023-1/UF 17-354-302. It is part of a continuing program on the developing technology of TNT explosive systems.

The findings in this report are not to be construed as an official Department of the Navy position. While the data is believed to be accurate, it is subject to change and is therefore released as information at the working level.

W. J. MADDOCKS
Captain, USN
Commanding Officer

U. CORMIER
By direction

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EVALUATION OF LOW COST ALUMINUM ALLOY GRANULES FOR USE IN ALUMINIZED EXPLOSIVES

I. INTRODUCTION

The feasibility of replacing the atomized aluminum (MIL-A-512), Type III, Grade F, Class 7) currently used in high explosive compositions with lower cost aluminum alloy granules (ALMEG EXXO 90-30) was investigated on a laboratory scale. ALMEG EXXO 90-30 is marketed by ALMEG, Inc., Kansas City, Missouri. It is reportedly obtained from scrap consisting essentially of aluminum alloy 7075. It is ground to a coarse mesh product (nominal 30 mesh) with a maximum of 2 percent finer than 200 mesh. The manufacturer quotes a price of 20 to 22 cents per pound in quantity lots; current price for the atomized aluminum is 25 cents per pound (1).

The alloy was incorporated into aluminized explosive mixes which were evaluated with respect to flow properties, settling, porosity and composition uniformity. The explosives Tritonal, DESTEX and H-6 were selected as being representative. Atomized aluminum was used in control batches.

Samples from the explosive batches were tested for thermal stability and impact sensitivity. The particle size distribution and chemical composition of the two types of aluminum used in the explosive batches were compared.

Preliminary tests of the compatibility of Minol 2 components with ALMEG EXXO 90-30 were included as part of this study. Minol 2 is an aluminum/TNT mixture in which a portion of the TNT is replaced with ammonium nitrate.

II. EXPERIMENTAL AND RESULTS

A. Batch Processing

Laboratory batches were prepared of the following aluminized explosives:

1) Tritonal (80/20, TNT/Al)

2) DESTEX (80/20/5/2/0.1, TNT/Al/D-2/acetylene carbon black/ lecithin)

3) H-6 (74/21/5, Comp B/Al/D-2)

One batch of each explosive was prepared using the lower cost, coarse, aluminum alloy granules, ALMEG EXXO 90-30. A comparison batch of each was prepared with atomized aluminum, MIL-A-512, Type III, Grade F, Class 7, nominal 40 mesh.

One thousand-gram laboratory batches were mixed in a half-gallon laboratory steam heated kettle equipped with an impellator agitator driven by an air motor. The regular batching procedure of melting the TNT or Comp B and incorporating the aluminum powder into the molten material was followed. After the addition of the last component, medium agitation (speed 750 to 1,000 rpm) was continued for 15 minutes at 95°C.

Viscosity determinations were attempted on the molten explosives before casting. Measurements were taken with a Brookfield viscosimeter, RVT Model, spindle #4, 0.5 rpm at 95°C. It was only feasible to obtain actual viscosimeter readings on the DESTEX mixes. Viscosity values were in the range of 38,000 to 52,000 centipoises with the lower value being obtained for the atomized aluminum system and the higher value for the ALMEG system.

After the batches were mixed, six sticks were cast from each batch by decanting from the tilt-type kettle. Sticks #1 and #2 represented the top, #3 and #4 the middle, and #5 and #6 the bottom of the kettle. The preheated aluminum molds for the sticks were 1 inch in diameter and 4 inches high. Each mold was equipped with an aluminum riser 2 inches in diameter and 3 inches high. Sticks #1 and #2 were solidified at ambient temperature; sticks #3 and #4 were held at 90°C. for 4 hours and sticks #5 and #6 were held at 90°C. for 8 hours before being allowed to solidify. After solidification, the riser explosive was removed and the test specimens were sampled.

B. Batch Testing

Samples were taken from the top, middle and bottom 1/2 inch of the sticks. Densities were determined on the 1/2-inch samples before grinding. They were reduced in a wooden mortar with a wooden pestle to pass a 20 mesh U. S. Standard Sieve and analyzed for aluminum content. Because of the extra analytical time that would have been required, and because it would not have significantly changed the values with respect to evaluating settling of the aluminum, the aluminum and carbon black contents were reported together. Tables I, II and III give the analytical data on the segregation sticks.

A representative sample was selected from each batch and tested for vacuum stability, impact sensitivity, and thermal behavior. Included in the vacuum stability test and differential thermal analysis (DTA) were the components of Minol 2 (TNT and ammonium nitrate) in contact with the ALMEG aluminum.

The vacuum stability was tested at 100°C. for 48 hours. A one-gram sample was used. All cast explosives were reduced thru a 20 mesh U. S. Standard Sieve; the TNT, ammonium nitrate, ALMEG aluminum and atomized aluminum were used as received in granular form. The test procedure was similar to the conventional vacuum stability test described in MIL-STD-650.

The impact sensitivity test followed the Bruceton Method on a Bruceton style machine equipped with Type 12 tools and 2.5 kg. weight. The impact sensitivity height value was determined from 25 shots per run, with 35 ± 2 mg. weight of explosive per shot on No. 5/0 sandpaper.

The differential thermal analysis curves were recorded by a Stone Differential Thermal Analyzer equipped with a X-Y recorder. Heating rate was 10°C. per minute. Sample size was 20 mg. for the explosives Tritonal, DESTEX, H-6 and for the single components; sample size of 40 mg. was used for the Al-NH_4NO_3, Al-TNT and Al-NH_4NO_3-TNT systems. Thermal studies and sensitivity results are tabulated in Table IV.

C. Aluminum Particle Size Analysis

A sieve analysis of the ALMEG EXXO 90-30 and the atomized aluminum was run. U. S. Standard Sieves were used on a Ro-Tap mechanical shaker geared to produce 150 taps of the striker per minute. Results are tabulated in Table V.

III. DISCUSSION OF RESULTS

A. Explosive Batching

The processing problems signified by the composition and density results in Tables I, II and III are of such a nature that new batching techniques would have to be developed for Tritonal and H-6 should ALMEG EXXO 90-30 be used in lieu of regular atomized aluminum. Inadequate suspension of the aluminum and porosity of the explosive were the major problems.

When ALMEG aluminum was incorporated into a laboratory Tritonal batch, it would not remain suspended during mixing at normal agitation. This resulted in a sizable percentage of aluminum remaining in the kettle after the liquid portion of the slurry had been cast. Figure 1 photographically demonstrates the lack of aluminum in all segregation sticks poured from Tritonal-ALMEG batches. No viscosity data was obtainable because of this severe aluminum settling problem.

The H-6 prepared with the ALMEG aluminum had low density values, a high degree of porosity and poor uniformity of composition. There was a density gradient of 1.788 to 1.697 g/ml from top to bottom in the sticks that were held 4 to 8 hours at 90°C. Figure 2 is a photograph of H-6

segregation sticks showing the increase in porosity with ALMEG aluminum. There was an apparent tendency for the TNT-wax to flow away from the large aluminum particles, resulting in poor riser action and the outer layer of TNT and wax that can be seen in Figure 2. This would cause problems in production with respect to riser feed and would cause aluminum to be left behind to clog kettle valves. This lack of wetting of the aluminum by the TNT and wax also contributed to the severe porosity problem encountered in the H-6, only part of which appeared to be due to entrapped air. Some separation of the TNT and ALMEG aluminum occurred in the kettle as soon as agitation was stopped. This was evidenced by the difference in aluminum content between the first two and the last four sticks cast from the batch. Even though viscosity values could not be obtained because of this separation in the kettle, it was apparent that the ALMEG H-6 was thicker than normal H-6. This higher viscosity was verified by the reduced agitator speed for the same amount of air pressure applied to the agitator.

When ALMEG aluminum was used in the preparation of a DESTEX slurry, it did not settle but the melt composition was not as uniform as that with atomized aluminum. There was a spread of 4.6 percent in the aluminum-carbon black content in the ALMEG DESTEX versus 1.0 percent for the atomized aluminum DESTEX.

The difference in thickening power of the two aluminums was not as noticeable in the DESTEX formulations because the primary thickening agent in DESTEX is a structural carbon black. This difference in the aluminums becomes significant in H-6 in which the dominant thickening agents are RDX and the aluminum.

B. Stability

The vacuum stability, DTA and impact sensitivity data did not show any immediate chemical incompatibility problems. However, DTA thermograms indicated that the ALMEG aluminum hastened the decomposition of the ammonium nitrate once the nitrate was in the molten stage.

MIL-A-512 for atomized aluminum, Grade F, requires an aluminum of 98.75% minimum purity. Copper, iron and silicon are limited to a maximum of 0.5% each, magnesium to 0.1% maximum and zinc to 0.25% maximum. The aluminum alloy granules, ALMEG EXXO 90-30, if obtained from the aluminum alloy 7075, have a nominal composition of 1.6% copper, 2.5% magnesium, 0.30% chromium, and 5.6% zinc. The long range effect of these impurities on the various explosive systems has not been tested when the impurities were present in alloy form except as noted in reference (2).

An experiment (2) at Picatinny Arsenal in which a magnesium-aluminum alloy was tested in contact with dry Amatol (TNT/NH_4NO_3, 50/50) resulted in heavy tarnishing of the alloy. This same test found that

aluminum metal is far superior to either magnesium or the magnesium-aluminum alloy to corrosion resistance in the presence of moist (0.5% H_2O) TNT or moist Amatol. The magnesium-aluminum alloy was also corroded by the presence of moist (0.5% H_2O) Comp B but not to the extent caused by the TNT or Amatol. This alloy was identified as J-1.

The literature (3) reports that in the presence of moisture, ammonium nitrate reacts with copper to form tetraminocupric nitrate which is of the same order of sensitivity to impact as lead azide. Bourjol (4) reported samples of Amatol stored for 25 years in zinc boxes caused deterioration of the TNT. This did not occur when aluminum boxes were used. Atmospheric corrosion of zinc (5) produces a hydrated basic carbonate $ZnO:CO_2:H_2O$ as 5/4/8 or 5/2/3 or 4/1/3 or 4/1/4. Different external conditions at time of formation affect the final composition. Basic materials(as distinguished from acidic) are incompatible with TNT.

These references from the literature to conditions which could cause adverse chemical reaction, are serious enough to question the advisability of using any aluminum such as ALMEG EXXO 90-30 which has sizable percentages of other metallic impurities incorporated in it.

C. Particle Size

The sieve analysis data (Table V) emphasizes the particle size distribution differences between the two kinds of aluminum. Ninety-seven percent of the ALMEG material was retained on a U. S. Standard Sieve No. 100 (149 microns) as compared to 22% of the atomized aluminum. This absence of fine particles is the reason the ALMEG material gives a thicker slurry and one which does not flow as well with respect to riser feed. The ALMEG has 64% of "on 50 mesh" granules as compared to 4% for the atomized aluminum. "On 50 mesh" (297 microns) aluminum is extremely difficult, because of its large size, to keep in suspension in a slurry without the addition of a suspension agent and will settle out of the melt before the mix can be poured from the kettle.

It was reported in a study (6) by a joint Project Manager - Picatinny Arsenal Air Force Team, that the use of coarse aluminum alone in Tritonal increased sensitivity to impact at low energy levels.

IV. CONCLUSIONS

The coarse, granular aluminum alloy, ALMEG EXXO 90-30, is not a satisfactory substitute for atomized aluminum (MIL-A-512, Type III, Grade F, Class 7, nominal 40 mesh) being used in current explosive formulations; i.e. Tritonal, H-6 and Minol 2. It produces explosive melts in which either settling, porosity, or composition uniformity levels are unacceptable. The elimination of these factors would require extensive process modifications with respect to batching

temperature and agitation speed and could require vacuum treatment of the explosive melt. Also flow problems would be experienced with respect to riser feed and obstruction of kettle valves.

ALMEG EXXO 90-30 meets explosive melt criteria in a system (DESTEX) employing a suspension agent but even here the results are marginal.

There is a high potential of hazardous chemical reactions arising in long term storage under humid conditions. With respect to ammonium nitrate, chemical reaction could take place even under dry conditions.

The cost differential between the ALMEG EXXO 90-30 and currently used atomized aluminum (MIL-A-512, Type III, Grade F, Class 7) is not great enough to justify its substitution in short term storage aluminized explosive systems in view of the large number of processing problems which would be encountered.

V. REFERENCES

(1) NAVORD OD 12067-C, Index to Navy Ammunition Stock Class C Military Chemical, 1 July 1968 and November 1968

(2) Eriksen, E. L., TR 1493, Action of Explosives on Metals used in Ammunition, Picatinny Arsenal, Jan 1945, pp. 2,3, AD 655282

(3) TM 9-1910, Military Explosives, 1955, p. 120

(4) PATR 2700, Ency. of Explosives and Related Items, Vol.1, p. A161

(5) Ency. of Chemical Technology, Vol. 15, 1956, p. 226

(6) Kolis, K., and Pietrzak, R., Final Report of Investigation M117A1 750 Pound Bomb Explosive Incidents (U), AMCPM-BR TR 117, Nov 1968, p. 20, AD 394064

TABLE I

COMPOSITION AND DENSITY ANALYSIS OF SEGREGATION STICKS
TRITONAL (80/20, TNT/Al)

Sample locations	ALMEG EXXO 90-30 Composition TNT (%)	ALMEG EXXO 90-30 Composition Al (%)	ALMEG EXXO 90-30 Density (g/ml)	Atomized Al MIL-A-512, Type III, Grade F, Class 7 Composition TNT (%)	Atomized Al Composition Al (%)	Atomized Al Density (g/ml)
STICK NO. 1*						
Top 1/2"	100.0	0.0	1.567	88.1	11.9	1.639
Middle 1/2"	100.0	0.0	1.565	85.0	15.0	-
Bottom 1/2"	94.6	5.4	1.613	46.7	53.3	2.021
STICK NO. 2*						
Top 1/2"	100.0	0.0	1.563	91.2	8.8	1.640
Middle 1/2"	100.0	0.0	1.570	86.3	13.7	-
Bottom 1/2"	91.3	8.7	1.651	46.2	53.8	2.024
STICK NO. 3**						
Top 1/2"	100.0	0.0	1.581	99.8	0.2	1.569
Middle 1/2"	99.9	0.1	1.569	99.8	0.2	1.564
Bottom 1/2"	69.1	30.9	-	41.5	58.5	2.073
STICK NO. 4**						
Top 1/2"	99.9	0.1	1.583	99.8	0.2	1.569
Middle 1/2"	100.0	0.0	1.572	99.8	0.2	1.569
Bottom 1/2"	69.7	30.3	-	41.1	58.9	2.080
STICK NO. 5***						
Top 1/2"	100.0	0.0	1.577	99.9	0.1	1.573
Middle 1/2"	100.0	0.0	1.580	99.7	0.3	1.576
Bottom 1/2"	68.5	31.5#	1.830	42.8	57.2	2.083
STICK NO. 6***						
Top 1/2"	100.0	0.0	1.570	99.9	0.1	1.580
Middle 1/2"	100.0	0.0	1.573	75.5	24.5	1.862
Bottom 1/2"	63.6	36.4#	1.855	41.7	58.3	2.030

Solidification condition:
*Ambient cooling (top 1/3 of batch)
**4 hrs. at 90°C., ambient cooling (middle 1/3 of batch)
***8 hrs. at 90°C., ambient cooling (bottom 1/3 of batch)
#Patty from kettle melt had 55.7% Al

TABLE II

COMPOSITION AND DENSITY ANALYSIS OF SEGREGATION STICKS
DESTEX
(80/20/5/2/0.1, TNT/Al/D-2/acetylene carbon black/lecithin)

	Type of Aluminum			
	ALMEG EXXO 90-30		Atomized Al MIL-A-512, Type III, Grade F, Class 7	
Sample locations	Composition Al + carbon black (%)	Density (g/ml)	Composition Al + carbon black (%)	Density (g/ml)
STICK NO. 1*				
Top 1/2"	20.4	1.679	20.5	1.671
Middle 1/2"	20.0	1.673	20.7	1.675
Bottom 1/2"	20.6	1.682	20.6	1.681
STICK NO. 2*				
Top 1/2"	19.9	1.674	20.4	1.672
Middle 1/2"	21.8	1.675	20.6	1.677
Bottom 1/2"	20.9	1.684	20.6	1.684
STICK NO. 3**				
Top 1/2"	18.9	1.663	20.7	1.662
Middle 1/2"	20.0	1.656	20.5	1.665
Bottom 1/2"	22.3	1.668	20.8	1.678
STICK NO. 4**				
Top 1/2"	19.8	1.666	20.5	1.658
Middle 1/2"	21.5	1.659	20.4	1.662
Bottom 1/2"	23.5	1.671	20.9	1.650
STICK NO. 5***				
Top 1/2"	20.2	1.663	20.6	1.651
Middle 1/2"	21.5	1.653	20.7	1.658
Bottom 1/2"	22.7	1.660	21.4	1.674
STICK NO. 6***				
Top 1/2"	21.2	1.663	20.6	1.659
Middle 1/2"	21.3	1.655	20.7	1.634
Bottom 1/2"	21.3	1.668	21.1	1.649

Solidification condition:
*Ambient cooling (top 1/3 of batch)
**4 hrs. at 90°C., ambient cooling (middle 1/3 of batch)
***8 hrs. at 90°C., ambient cooling (bottom 1/3 of batch)

TABLE III

COMPOSITION AND DENSITY ANALYSIS OF SEGREGATION STICKS
H-6 (74/21/5, Comp B/Al/D-2)

Sample locations	ALMEG EXXO 90-30 Composition Al (%)	ALMEG EXXO 90-30 Density (g/ml)	Atomized Al MIL-A-512, Type III, Grade F, Class 7 Composition Al (%)	Atomized Al MIL-A-512, Type III, Grade F, Class 7 Density (g/ml)
STICK NO. 1*				
Top 1/2"	22.0	1.692	21.5	1.740
Middle 1/2"	22.3	1.690	21.2	1.737
Bottom 1/2"	21.9	1.704	21.2	1.747
STICK NO. 2*				
Top 1/2"	21.2	1.688	20.6	1.741
Middle 1/2"	21.9	1.698	21.2	1.746
Bottom 1/2"	20.8	1.707	21.1	1.753
STICK NO. 3**				
Top 1/2"	25.6	1.769	20.7	1.733
Middle 1/2"	24.4	1.727	21.0	1.729
Bottom 1/2"	23.5	1.690	22.4	1.719
STICK NO. 4**				
Top 1/2"	26.7	1.788	19.7	1.735
Middle 1/2"	24.1	1.739	20.1	1.736
Bottom 1/2"	25.4	1.697	21.7	1.729
STICK NO. 5***				
Top 1/2"	25.2	1.795	20.5	1.720
Middle 1/2"	24.8	1.738	21.7	1.732
Bottom 1/2"	23.7	1.703	22.5	1.724
STICK NO. 6***				
Top 1/2"	25.8	1.771	20.2	1.727
Middle 1/2"	26.1	1.731	21.6	1.732
Bottom 1/2"	25.7	1.739	22.5	1.759

Solidification condition:
*Ambient cooling (top 1/3 of batch)
**4 hrs. at 90°C., ambient cooling (middle 1/3 of batch)
***8 hrs. at 90°C., ambient cooling (bottom 1/3 of batch)

TABLE IV

THERMAL AND SENSITIVITY RESULTS COMPARING
ALMEG AND ATOMIZED ALUMINUM IN VARIOUS EXPLOSIVE MIXES

Sample	Vacuum stability (ml/g/48 hrs/ 100°C./STP)	* Impact sensi-tivity 50% ht (cm)	DTA**		
			Endotherm	Exotherm	
				Initial	Max. $\frac{\Delta T}{T}$
			(°C.)	(°C.)	(°C.)
Tritonal (ALMEG)***	0.3	209	81	215	234
Tritonal (At-Al)****	0.2	186	80	218	235
DESTEX (ALMEG)	0.1	285	80	223	307
DESTEX (At-Al)	0.2	320	80	184	235
H-6 (ALMEG)	0.1	102	80	190	215
H-6 (At-Al)	0.1	99.3	80	186	211
ALMEG/NH_4NO_3 (50/50)	0.3	-	52,88, 140,164	234	288
At-Al/NH_4NO_3 (50/50)	0.1	-	-	-	-
ALMEG/TNT (50/50)	0.1	-	80	209	239
At-Al/TNT (50/50)	0.1	-	80	221	236
ALMEG/NH_4NO_3/TNT (50/25/25)	0.3	-	51,80, 128,166	213	245
At-Al/NH_4NO_3/TNT (50/25/25)	0.3	-	55,82,94, 129,165	229	236
TNT	0.1	144	-	-	-
NH_4NO_3	0.4	254	55,91,128, 165,222	293	293
NH_4NO_3/TNT (50/50)	0.4	-	52,80,92, 128,165	203	232
ALMEG	0.2	-	-	-	-
At-Al	0.2	-	-	-	-

*Type 12 tools, 2.5 kg. wt., 35 ±2 mg., No. 5/0 sandpaper
**Heating rate 10°C./min., 20 to 40 mg. sample wt.
***ALMEG EXXO 90-30
****Atomized Aluminum, MIL-A-512, Type III, Grade F, Class 7

TABLE V

SIEVE ANALYSIS*

U. S. Std. Sieve	Atomized Al** MIL-A-512, Type III, Grade F, Class 7 (%)	*** ALMEG EXXO 90-30 (%)
+8	0.0	0.0
-8 +16	0.0	0.0
-16 +20	0.0	0.0
-20 +50	3.8	64.2
-50 +80	12.1	2[illegible].6
-80 +100	5.8	3.5
-100 +pan	78.2	2.7

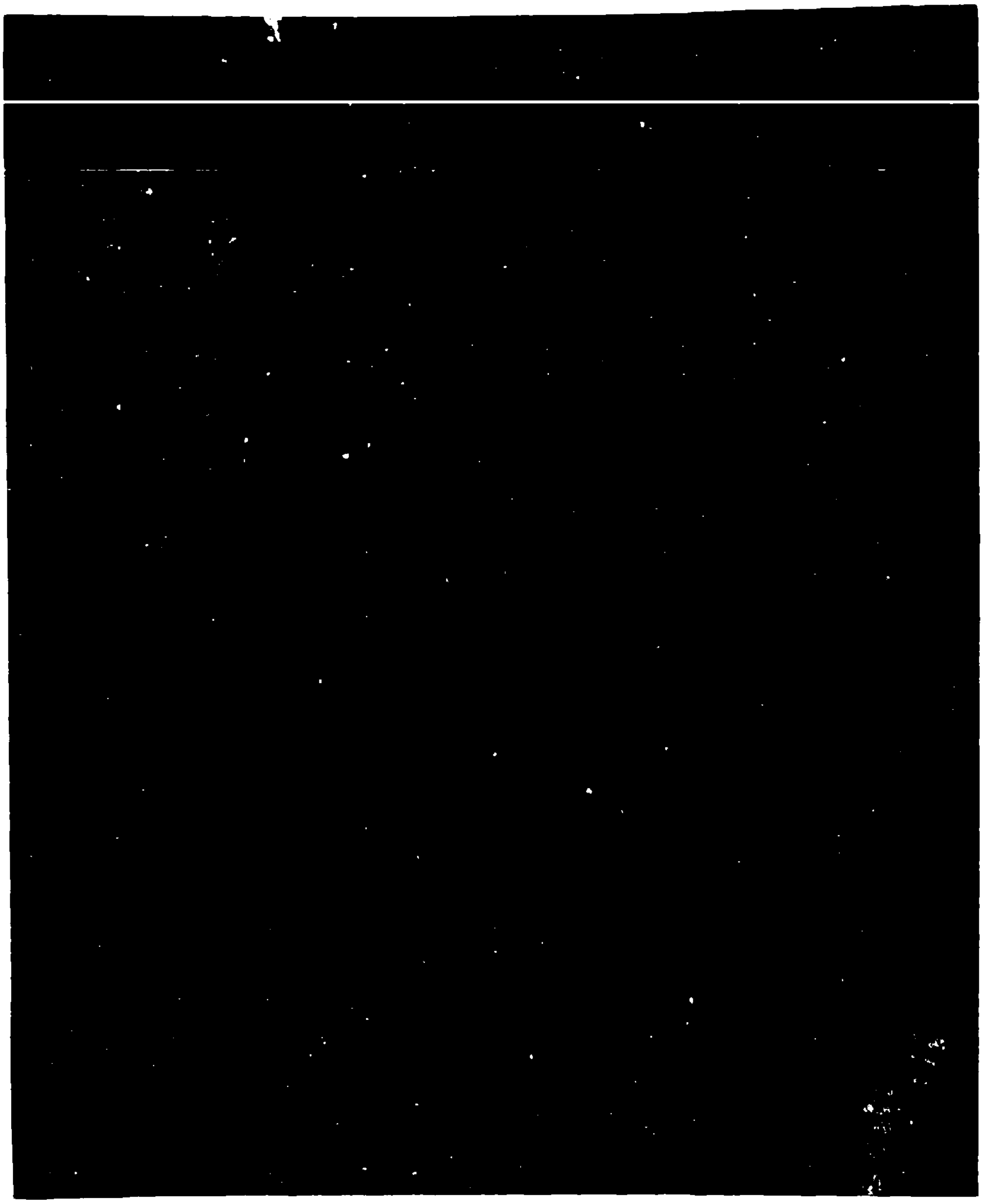
*100-gram, Ro-Tap, 10 minutes shaking time

**MIL-A-512 specification requirement for Type III, Grade F, Class 7, Atomized Aluminum:

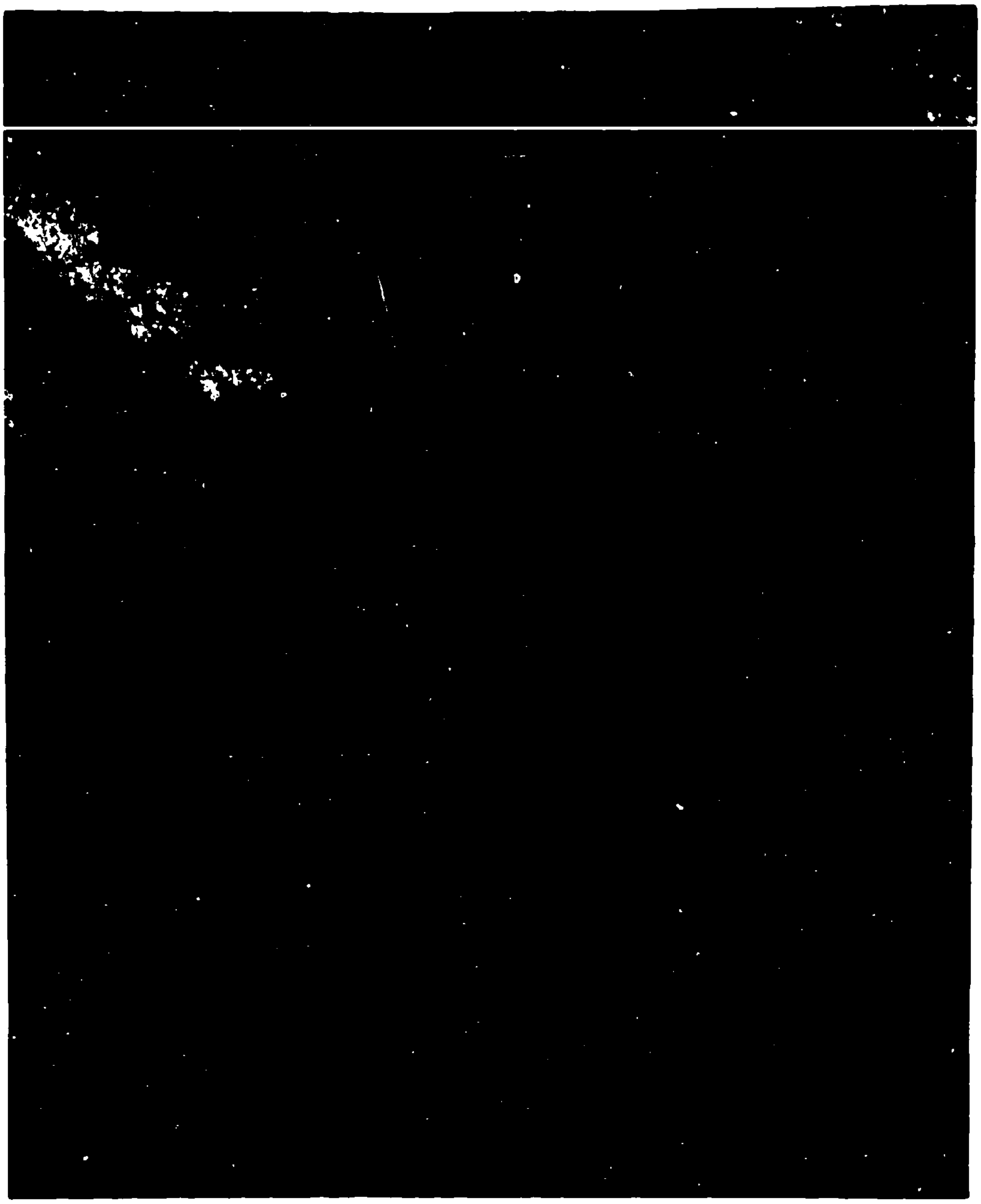
U. S. Std. Sieve	Percent retained
40	0.5 max.
230	70.0 max.
325	50.0 max.

***"Typical Mesh Range" of ALMEG EXXO 90-30 as described by manufacturer's literature:

U. S. Std. Sieve	Range (%)
+30	0-2
-30 +40	50-60
-40 +50	20-30
-50 +80	10-20
-80 +100	1-3
-100 +200	1-3
-200	0-2



SEGREGATION STICKS, TRITONAL
FIGURE 1



SEGREGATION STICKS, H-6
FIGURE 2

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14 KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
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Aluminum						
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